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EFFECT OF DIFFERENT SALT TREATMENTS ON SEED GERMINATION CHARACTERISTICS OF JUDAS TREE (*CERCIS SILIQUASTRUM* L.)

Naser Norouzi Haroni[1*], Masoud Tabari[1], and David Pothier[2]

[1]Faculty of Natural Resources, University of Tarbiat Modares. Noor Mazandaran, P. Box: 356-46414. Iran. *E-mail: norouzinaser88@yahoo.com

[2]Centre d'étude de la forêt, Département des sciences du bois et de la forêt, Pavillon Abitibi-Price, 2405 rue de la Terrasse, Université Laval, Québec, QC, G1V 0A6, Canada.

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Abstract

Seeds of Judas tree (*Cercis siliquastrum* L.) are characterized by coat-imposed dormancy related to the hardness and impermeability of their coat, and by endosperm dormancy due to the presence of ferulic acid around the seed endosperm, acting as chemical inhibitor. Some compounds including nitric acid gas, NO, NO_2^-, NO_3^-, nitrogen dioxide, ammonium, azide and cyanide stimulate germination process of different species. The present study was conducted to evaluate the effect of seed priming technique on some morphological characteristics of *Cercis siliquastrum* seeds. The results showed that seed priming with boiling water and nitrogenous compound could improve seed germination characteristics. Seed germination and survival were significantly affected by priming treatment with boiling water and chemical salts ($p < 0.001$). The greatest germination rate was observed with 500 mM KNO_3 for 48 h, while seed germination speed and shoot dry weight were maximized with 100 mM NH_4NO_3 for 48 h, vigor index with 500 mM NH_4NO_3 for 24 h and root dry weight with 100 mM NH_4NO_3 for 24 h. In addition, sodium chloride and potassium chloride treatments could not improve the germination characteristics and seedlet survivals of *Cercis siliquastrum.* These results confirmed that application of boiling water treatment and nitrogen-containing compounds could enhance germination rate and further seedling quality, and these treatments are thus extremely recommended in nurseries for improving seedling yield.

Key words: breaking dormancy, halopriming, root dry weight, salt solution treatment, shoot dry weight, vigor.

Introduction

Increasing global consumption of natural resources and ecological degradation, the annual net loss of world forest lands has reached 5.2 million hectares in the first 10 years of 21st century (FAO 2011). For example, the amount of forest degradation in Iran during last years has reached 2 million hectares (Kouhgardi et al. 2012). Hence, afforestation projects are very important in forest management of arid and semi-arid areas (Jazirei 2001). For this purpose, nurseries must produce high quality seedlings. This is particularly important for species having hard physical and physiological dormancy, like Judas tree (Dehghani 2005).

Cercis siliquastrum belongs to the subfamily Caesalpinioideae of the large plant family Fabaceae (Leguminosae). Genus *Cercis* currently includes about 10 recognized species scattered widely across the warm, north-temperate zones of North America and Eurasia (Fritsch et al. 2009). *Cercis siliquastrum* is native in southern Europe, the Crimea and Western Asia. In spite of being mostly a multi-stemmed tree, it can reach a height of 12 m in cultivation, albeit most individuals do not exceed 5 to 7 m (Raulston 1990). Flowers open at the beginning of spring, before the leaf flushing. Fruits mature at the end of summer or in autumn and remain on the plant for a long period of time. In the natural range of distribution of the species most of the annual rainfall (700–1000 mm) occurs between November and March, and only 5 % between May and September. It grows well on a variety of soil textures but performs best in soils with a pH above 7.5. It can tolerate some nutrient deficiencies and its growth is maximized in full sun. In Iran, *C. siliquastrum* is suitable for parks and gardens, and can be potentially used as a landscape tree, and as a phytoremediation measure against, for example, heavy metal deposits and dust storm (Yaşar et al. 2010). This species is well adapted to semi-arid conditions and can withstand hot dry summers provided that soil moisture is adequate in winter and spring. Judas trees can have many other applications such as border trees, for erosion control and windbreaks (Gebre and Karam 2004, Zahreddine et al. 2007).

Dormancy corresponds to a state of apparent metabolic arrest during which the normal progression of life activities and development is dramatically reduced or brought to a halt. Dormancy facilitates the survival of organisms exposed to environmental conditions that cannot support the regular course of life (Baskin and Baskin 1998). It can be regulated by the environment or by the seed itself. If a seed is not supplied with sufficient moisture or proper temperature, oxygen and light, its germination will be inhibited. Two types of dormancy are generally recognized: seed coat or external dormancy and internal (endogenous) dormancy. However, seeds of some species exhibit the so-called double dormancy, which is a combination of the two. To achieve germination in a case of double dormancy, seeds must be first scarified and then stratified for the appropriate prolonged period of treatment. If the treatments are administered in reverse order, the seeds will not germinate. After these treatments, seeds can be sown under proper environmental conditions for germination.

The seeds of Judas tree have double dormancy due, on the one hand, to the hardness and impermeability of the seed coat (Martinucci et al. 1985) and, on the other hand, to the presence of ferulic acid in the endosperm that acts as a chemical inhibitor (Pipinis et al. 2011). The dormancy of the *C. siliquastrum* seeds can be relieved by integument scarification. Conventional propagation requires different treatments because of the physical and physiological seed dormancy (Zencirkiran et al. 2010, Pipinis et al. 2011). Many studies have been conducted to break the dormancy of Judas tree seeds. Geneve (1991) and Dirr and Heuser (1987) tried to break the dormancy by cold stratification to allow imbibitions of the hard seed coat, but this method necessitates long periods of cold exposure to improve its efficiency. Also, while acid treatment of Judas tree seeds with combined effects of sulfuric acid and stratification resulted in high germination proportion, this method produced negative effects on seedling growth rate (Frett

and Dirr 1979, Liu et al. 1981) and is very time consuming. Over the last years, a new method has shown promising signs to improve the break of dormancy of tree seeds and the growth of seedlings (Bradford et al. 1990). During osmotic priming and/or halopriming, ions of potassium nitrate, sodium chloride, potassium chloride, sodium nitrate, calcium nitrate and ammonium nitrate solutions accumulate within the seeds and increase water absorption by reducing water potential (Parera and Cantliffe 1994). Successful results have been obtained with beans (Azooz 2009) and maize (Mehdi et al. 2008) under saline conditions. The advantages of halopriming in improving germination efficiency (Taylor et al. 1998), speed of germination (Bhan and Sharma 2011), growth rate (Guo et al. 2012), uniformity of germination and seed ling quality (Basra et al. 2005), popularized the application of this seed treatment in forestry.

Seeds of *C. siliquastrum* have a deep dormancy and are hard to germinate especially when dried. In this study, we investigated the simultaneous effects of boiling water and potassium nitrate, sodium chloride, potassium chloride, sodium nitrate, calcium nitrate and ammonium nitrate treatments on breaking the double dormancy and on germination of Judas tree seeds. The results could have potential to find an efficient and functional way to increase their germination.

Materials and Methods

Seed physical-and-chemical properties

The seeds of Judas tree used in this study came from the Central seed center of Caspian (Amol). Seed physical-and-chemical characteristics are presented in Table 1.

Table 1. Characteristics of the seed lot from Amol Caspian seeds Centre.

Species	Origin	Latitude	Longitude	Altitude, m	Climate	Viability, %	Humidity, %	Numbers per 1 kg	Weight of 1000 seeds, g	Purity, %
Cercis siliquastrum	Zanjan, Iran	36°66' N	48°48' E	1663	Semiarid ultra cold	85	4.4	36630	27.7	97

Seed treatments and germination tests

We selected seeds to homogenize their size and shapes before applying the thermo-halopriming treatments, randomly in order to their germination test. The seeds were soaked for 5 min in a solution containing 2 $g \cdot l^{-1}$ of carboxin thiram for disinfection and then washed with distilled water. After seed disinfection, they were put in boiling water whose temperature was then decreased to room temperature over a period of 24 h. Thereafter, to carry out halopriming, the seeds were soaked for 2 different periods (24 and 48 h) in solutions with three different osmotic potentials (100, 250 and 500 mM) produced by 6 chemical salts (potassium nitrate, sodium chloride, potassium chloride, sodium nitrate, calcium nitrate and ammonium nitrate). Seeds were then washed with distilled water and air dried. In addition, 2 non-priming treatments (soaked in boiling water for 24 and 48 h) and 1 control treatment (without soaking and priming) were

Table 2. The studied traits and calculating.

Germination indices	Equation
Germination rate	$GR = \frac{n}{N} \cdot 100$
Germination speed (Maguire 1962)	$GS = \sum \left(\frac{n_i}{t_i} \right)$
Mean time to germination (Abdul-Baki and Anderson 1972)	$MTG = \frac{\sum (n_i \cdot t_i)}{\sum n}$
Vigor index (Abdul-Baki and Anderson 1972)	$VI = (RL + SL) \cdot \frac{GP}{100}$

Note: n – the total number of seeds germinated in the period; N – the number of seeds planted; t_i – the number of days after the onset of germination; n_i – the number of germinated seeds in specified period of t_i; *RL* – mean or average rootlet length; *SL* – mean or average stem length; *GP* – percentage of seed germination.

applied to other groups of seeds. All treatments were conducted in a completely randomized design with 4 replications and 25 seeds within each treatment of each replication. After the application of each treatment, the seeds were placed on disinfected 9-cm glass Petri dishes with 2 layers of filter paper, each Petri dish containing 25 seeds. The Petri dishes were transferred to a germinator set at a temperature of 20 °C, with a 16:8 light period, 1000 lux light intensity and 60 percent humidity (ISTA 1985). The filter papers were replaced every 3 days to prevent contamination with fungi. We considered that seed germination occurred when radicles emerged from the seed coat and were at least 2 mm in length (Bradford et al. 1990). Seed germination was recorded daily during a period of 30 days, i.e. well after maximum germination was obtained.

Calculated variables and statistical data analyses

The following germination parameters were calculated: germination percentage (*GR*), germination speed (*GS*), mean time to germination (*MTG*) and for the VI calculation, after 30 days based on formulas presented in (Table 2).

Also, after 30 days, 10 cotyledons were randomly selected from each treatment and were used to measure growth characteristics such as shoot and root length using an electronic caliper with an accuracy of 0.01 mm, and fresh and dry weight of shoots and roots. Analyses of variance (ANOVA) were performed using the SPSS 16.0 software. Post-hoc Duncan test was used to evaluate the differences among means at 5 % level of probability.

Results

Analyses of variance (Table 3) revealed that boiling water and chemical salt treatments significantly improved the seed germination and seedling survival ($p < 0.001$). Among the priming treatments, the highest seed germination rate (*GR*) was ob-

Table 3. Mean squares of analysis of variance (ANOVA) for seed quality traits evaluated after priming with six salt solutions during 24 and 48 hours.

Source of variation	df	Germination, %	Speed of germination, seeds per day	Mean time to germination, days	Shoot length, mm	Root length, mm	Vigor index	Shoot dry weight, mg	Root dry weight, mg
Salt	5	9520.44**	4.84**	339.70**	4631.10**	46.43**	4692.07**	1125.86**	75.73**
Time	1	1296**	1.20**	24.67^{ns}	236.68**	279.4**	1166.33**	28.78**	8.19**
Concentration	2	589.77**	0.18**	58.05**	65.32*	47.02^{ns}	216.16**	12.41**	3.09**
S×*C*	10	623.91**	0.50**	41.03**	133.59**	116.99**	275.73**	33.94**	3.64**
S×*T*	5	654.93**	0.62**	7.21^{ns}	220.05**	421.547**	451.01**	132.18**	7.23**
T×*C*	2	233.33**	0.18**	19.25^{ns}	82.24**	272.51**	316.51**	8.93**	2.11**
S×*T*×*C*	10	239.46**	0.24**	5.89^{ns}	243.86**	93.33**	184.312**	45.62**	4.09**
Error	108	28.14	0.02	10,61	14.55	24.80	7,14	0.00	0.00

Note: * – significant difference at $P < 0.05$; ** – significant difference at $P < 0.01$; *ns* – non-significant; *S* – salt; *T* – time; *C* – concentration.

served in the treatment using 500 mM of KNO_3 during 48 hours (64 %) whereas the lowest *GR* was observed with 100 mM of KCl during 24 hours (1 %) (Table 3).

No germination was recorded in the control treatment. Among the chemicals used for priming, KCl, NaCl and boiling water were associated with lower seed germination. Also, seed germination speed (*GS*) was improved with chemical and boiling treatments. The highest value of GS was observed for the treatment consisting of 100 mM of NH_4NO_3 during 48 hours whereas the lowest value was observed with 100 mM of KCl during 24 hours. In the case of the mean germination time (*MTG*), the lowest value was observed with100 mM of KCl during 24 hours and the highest value with 500 mM of NaCl during 48 hours.

The growth characteristics of seedlings improved in all priming treatments. The highest value of shoot length was observed with 250 mM of KNO3 during 24 h while root length and vigor index were maximized with 500 mM of NH_4NO_3 during 24 h and 500 mM of NH_4NO_3 during 24 h, respectively (Table 4). Also, maximum values of shoot and root dry weight were observed with 100 mM of NH_4NO_3 during 24 h and 500 mM of $CaNO_3$ during 24 h, respectively (Fig. 1 and 2).

Discussion

Some compounds, including nitric acid gas, NO, NO_2^-, NO_3^-, nitrogen dioxide, ammonium, azide and cyanide, have been found to stimulate the germination of different species (Bradford and Nonogaki 2007). Generally, pretreating seed resulted in better germination, establishment of seedlet and seedling production (Farooq et al. 2007, Harris et al. 1999). In the present study, we aimed to break dormancy of *C. siliquastrum* seeds, which are characterized by 2 types of dormancy, A: a primary dormancy resulting from their hard and impermeable coat (Riggio-Bevilacqua and Tornabuoni 1974), and B: a secondary dormancy (endosperm)

Table 4. Effect of boiling water and chemical treatments on seed germination and seedling survival.

Treatment	Time, h	Concentration, mM	Germination, % ± S.D.	Speed of germination, seed on day	Mean time to germination, days	Shoot length, mm	Root length, mm	Vigor index
Sodium chloride	24	100	6(2,3)no	0,0(0,02)hi	19(3,3)abc	17(3,3)jklmn	7(0,78)lm	1,45(0,23)opq
		250	7(2)mno	0,1(0,01)hi	16,8(4,5)bc	14,8(1,7) mnop	7,2(1,6)lm	1,54(0,18)opq
		500	9(3.8)lmno	0,1(0,07)hi	20,5(3,07)ab	16,4(3,9) klmno	7,9(2)klm	2,19(0,41)opq
	48	100	8(3,2)mno	0,1(0,10)hi	15,5(3)bcde	17,2(3,1)ijkmn	7,2(0,8)lm	1,96(0,3)opq
		250	8(3,2)mno	0,1(0,03)hi	17,5(3,6)abcd	12,3(3,3)p	6,3(0,19)m	1,46(0,51)opq
		500	9(3,8)lmno	0,1(0,06)hi	22(4)a	13,9(33,3)nop	6,6(1,8)lm	0,20(0,05)pq
Potassium chloride	24	100	1(2)o	0,02(0,04)i	3(6)g	0,00(0,00)q	0,00(0,00)q	0,00(0,00)q
		250	4(3,2)no	0,08(0,07)hi	10,5(7,1)ef	0,00(0,00)q	0,00(0,00)q	0,00(0,00)q
		500	2(2,3)no	0,03(0,04)i	6,75(7,8)fg	0,00(0,00)q	0,00(0,00)q	0,00(0,00)q
	48	100	2(4)no	0,03(0,07)i	3,25(6,5)g	0,00(0,00)q	0,00(0,00)q	0,00(0,00)q
		250	7(2)mno	0,12(0,05)hi	15,1(3,6)bcde	14,1(2,7)nop	9,9(2,4)hiklm	1,68(0,02)opq
		500	3(2)no	0,07(0,05)hi	7,5(5,4)fg	0,00(0,00)q	0,00(0,00)q	0,00(0,00)q
Sodium nitrate	24	100	17(2)jkl	0,32(0,05)fgh	15,5(0,05)bcde	19,5(2,2)jhijk	11,6(4,1)fghikl	5,30(0,92)mn
		250	22(2,3)hijk	0,43(0,16)fg	15,4(0,35)bcde	35,5(7,6)a	15(4,1)efgh	10,6(1,7)jk
		500	47(3,8)def	1,09(0,1)cd	13,7(0,97)cde	34,3(7,7)a	13,9(4,6)ef	22,7(4,4)bc
	48	100	20(5,65)ijk	0,43(0,16)fg	14(1,47)cde	27,4(3,2)bc	12,5(1,7)fghik	8(0,7)l
		250	19(2)ijk	0,32(0,02)fgh	16,7(1,9)abcd	29,2(2,4)defg	10,7(1,5) ghiklm	6,4(0,7)lm
		500	10(2,3)lmn	0,22(0,04)ghi	16,5(1,2)bcd	19,9(2,7)ghijk	9,3(1)hiklm	2,92(0,3)nop
Potassium nitrate	24	100	25(3,8)ghij	0,43(0,08)fg	16,5(1,1)bcd	12,4(1,5)p	5,4(0,42)hiklm	5,4(0,4)mn
		250	54(2.3)bcd	0.96(0.1)de	17.6(2)abcd	14.9(2.1) lmnop	13.5(1.2)hiklm	13.5(1.2)hi
		500	58(6.9)abc	1.19(0.26) bcd	16.3(0.46)bcd	13.4(3.5)nop	13(3.4)hiklm	21.5(11)de
	48	100	31(8.8)g	0.51(0.18)f	17.1(1.5)abcd	12.5(1.8)op	6.4(0.95)iklm	6.5(0.95)lm
		250	58(6.9)abc	1.11(0.12)cd	16.3(1.8)bcd	13.4(2.2)nop	12.3(1.5)klm	12.3(1.5)ij
		500	64(4.6)a	1.23(0.01)bc	16.4(1.3)bcd	12.9(1.8)op	13(1.4)ef	13 (1.4)hij
Calcium nitrate	24	100	54(6,9)bcd	1,42(0,2)ab	14.9(2.3)cd	28.6(2.5)b	18.9(2.88)c	25.6(1.9)d
		250	62(5.1)ab	1.64(0.4)a	14.3(1.5)cde	25(3.3)bcde	25.5(7.3)b	31.3(5)b
		500	42(9.2)f	0.78(0.1)e	15.8(1.9)bcde	21.6(2.9)efghi	27.4(6.8)ef	20.6(3.4)de
	48	100	32(8)g	0.54(0.1)f	17.2(0.3)abcd	18.7(3.9)hijkl	24 (8.3)cd	13.7 (2.67)hi
		250	30(6.9)gh	0.49(0.1)f	17.3(0.9)abcd	20.7(2.1)fghij	29.6(11.3)b	15 (3.5)gh
		500	30(5.1)gh	0.51(01)f	17.1(1.4)abcd	21.8(2)efghi	26.1(8.1)bc	14.4(2.8)hi
Ammonium nitrate	24	100	48(9.7)def	1.16(0.34)cd	13.7(0.7)cde	20.5(6.1)fghij	26.5(11.6)d	22.5(7.25)d
		250	45(10.5)ef	1.04(0.2)cd	13.4(0.9)cde	22.4(4.1) defgh	19.8 (8)de	19(5.15)ef
		500	60(3.2)abc	1.47(0.33)a	13.7(2.1)cde	26(4.4)bcd	35.6 (11.9)a	37(7.8)a
	48	100	52(5.6)cde	1.49(0.13)a	13.4(0.7)de	22.7(4.5)defg	18.5(5.3)d	21.4(2.7)de
		250	26(6.9)ghi	0.45(0.13)fg	17.9(1.8)bcd	18.1(6.4)ijklm	15.7(4.1)efg	8.8(2.1)kl
		500	46(5.1)def	1.16(0.26)cd	13.7(1.7)cde	24.3(6.6)cdef	13.3(5.5)fghi	17.3(2.35)fg
Boiling water	24	–	10(2.3)lmn	0.14(0.04)hi	17.9(1.8)abcd	14.7(3.7) mnop	14.7(3.7)cde	2.12(0.47)opq
	48	–	15(2)klm	0.21(0.03)ghi	18.7(0.4)abc	16.5(3.2) klmno	16.5 (3.2)f	3.43(0.57)opq

Note: Different letters indicate significant difference between seed treatment means according to Duncan's multiple range tests at the 0.05 significance level. Number in brackets represents standard deviation.

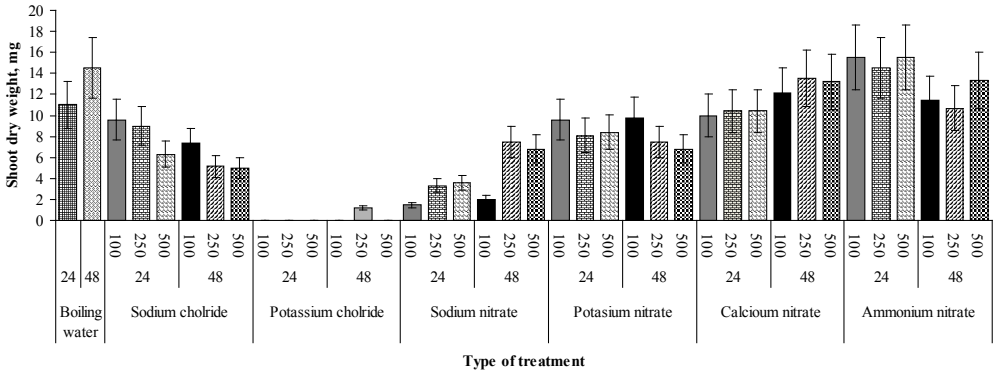

Fig. 1. Effect of different chemical treatments applied at various levels on shoot dry weight of primed and non-primed (boiling water) seeds (mean ± standard error).

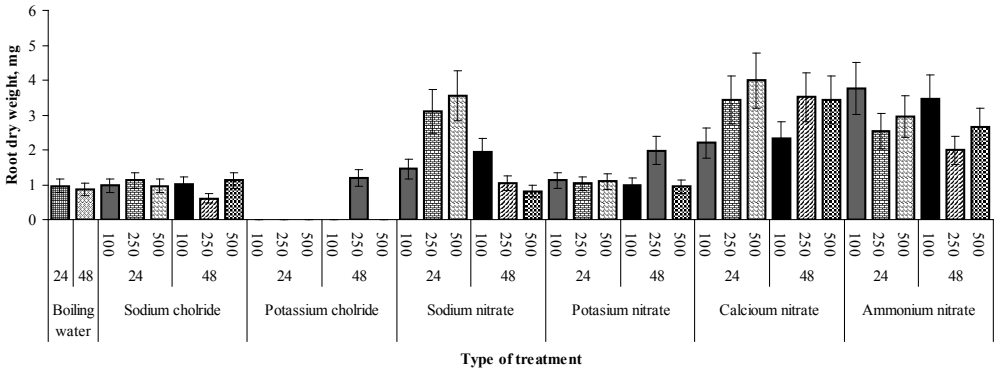

Fig. 2. Effect of different chemical treatments applied at various levels on root dry weight of primed and non-primed (boiling water) seeds (mean ± standard error).

caused by the presence of ferulic acid that inhibits the absorption of oxygen and water by the embryo.

Our results showed that salt treatments, differing in concentrations and time duration, significantly improved germination and primary growth of *C. siliquastrum* species. The highest germination percentages were found in scratching treatments with potassium nitrate and ammonium nitrate likely because of the presence of nitrite (NO_2^-) in these compounds (Sabina and Cornelia 2012). By altering the cell membrane, nitrate (NO_3^-) and nitrite (NO_2^-) allow materials to penetrate into the seed (Bethke et al. 2006) which, in turn, improve plant growth (Hendricks and Taylorson 1974). In addition, Roberts (1969) suggested that nitrogen-containing compounds could act as electron-accepting agents or could stimulate the transport of materials into the seed using NADPH oxidation[1]. These results are supported by many observations of the influence of nitrogen-containing compounds for stimulating the germination of various species (Stokes 1965, Bewley and Black

1994, Li et al. 2005).

The poor germination rate in seeds without any treatments could be explained by the physical characteristics of the seeds of Judas tree characterized by a thick crust containing several thick pectin and hemicellulose layers that become impermeable and hydrophobic during the last step of maturation (Comer 1976). In addition, the seed glazed layer prevents transporting oxygen and water into the seed endosperm (Riggio-Bevilacqua et al. 1985, Rascio et al. 1998). The highest germination rate was associated with ammonium nitrate, calcium nitrate, potassium nitrate, and sodium nitrate treatments. These results could be explained by the influence of boiling water to break seed dormancy and by the effect of nitrate to break endosperm dormancy and eliminate the ferulic acid layer (Bergmark et al. 1992). These results are consistent with Guo et al. (2012), who assessed halopriming technique using KNO_3 on germination of *Pinus bungeana* Zucc. ex Endl. seeds, and of Bhan and Sharma (2011) who worked with *Prunus armeniaca* L. using the same salt. Henig-Sever et al. (2000) concluded that NH_4^+ and NO_3^- exerted a positive effect on lipase activity of *P. halepensis* Mill. seeds and that these compounds degraded lipids and stimulated germination compared to other compounds.

The lowest average germination time was observed with the potassium chloride treatment which was also associated with the lowest germination percentage. Among nitrate treatments, the lowest average germination time was found with ammonium nitrate applied at different concentrations, but this result can be explained by the high germination rate associated with the use of the compound (Farooq et al. 2005). NaCl and KCl pretreatments did not improve germination of *C. siliquastrum* seeds compared to other nitrate and boiling water treatments. This could be explained by the fact that the cell wall of seed endosperm contains a chemical inhibitor (Martinucci et al. 1985) that is not affected by NaCl and KCl to protect the seed embryo from the toxic effect of Cl^- and Na^+ (Khajeh-Hosseini et al. 2003). These results are not consistent with Elouaer and Hannachi (2012) who observed better germination parameters of *Carthamus tinctorius* seeds following pretreatments using NaCl and KCl.

The better germination indices associated with treatments containing NO_3^- could be explained by the nitrate property to be a molecule carrier, which increases absorbed materials into the plant (Scheible et al. 1997). The higher viability index for seedlet obtained from ammonium nitrate and calcium nitrate pre treatments compared to other treatments may result from the improvement of seedlet length and germination percentage (Eskandari and Kazemi 2011). This result agrees with those of Ruan et al. (2002) who worked on *Oryza sativa* L. and observed a higher viability index associated with primed seeds compared to unprimed seeds. The better stem length emerging from seeds pretreated with sodium nitrate, calcium nitrate and ammonium nitrate could be explained by their rapid germination (Farooq et al. 2005). Also, it could be the result of the effect of the main nitrogen source, NO_3^-, on plant growth that produced amino acid and nitrogen-containing compounds through a decrease in nitrate reductase and other enzymes (Scheible et al. 1997, Wang et al. 2003). The improved root length of seeds pretreated with ammonium nitrate and other compounds could be attributed to

[1]Nicotinamide adenine dinucleotide phosphate.

the stimulating effect of NO_3^- on root growth (Hilhorst and Karssen 1992). Also, the use of nitrate-containing pretreatments to enhance water absorption of seeds could be considered as a factor explaining the fast appearance of roots and their rapid growth compared to seeds without priming treatment (Harper et al. 1977). The higher dry biomass of above- and below-ground parts of seedlets treated with nitrate-containing compounds could be explained by the improved growth of radicles and plumules (Sivritepe et al. 1999).

Overall, our results demonstrate that pretreating seeds with nitrate-containing compounds was highly efficient to stimulate and reinforce the germination and other physiological characteristics of *C. siliquastrum* seeds. Therefore, using boiling water treatment and nitrogen-containing compounds such as potassium nitrate and ammonium nitrate can enhance germination percentage and germination rate in such a way that these treatments could be used to increase the production efficiency of seedlings in nurseries.

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